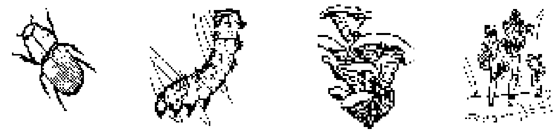
Forest Health Protection



Numbered Report 05-06 October 2005

CHANGES IN FIRE-KILLED WESTERN LARCH ON THE GLACIER VIEW RANGER DISTRICT (FLATHEAD NATIONAL FOREST), MONTANA

YEARS TWO, THREE, AND FOUR REPORT

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INTRODUCTION

This is the second of several reports describing progress in a ten- or more-year study evaluating changes of fire-killed western larch in northwestern Montana. Trees included were killed by the Moose Fire in fall 2001. This study will evaluate more than 300 trees (240 dissected), look at a large range (8 to 32 inch dbh) of sizes, and evaluate fire-killed trees over an extended period of time.

This report describes observations of all standing trees two and four years post-fire and tree dissections two and three years post-fire. Adult wood- and bark-boring insect collections and identifications are also discussed. The report continues with a discussion of progress by agents changing wood characteristics, and resulting reductions in merchantable volume, over the first three years of this study. For additional information about purpose, methods, and first year findings see Forest Health Protection Report 04-16 (Jackson 2004). More dissections are planned for five, seven, and ten years post-fire.

Collection and identification of wood- and bark-boring insects were added during the second year to better understand which insects are involved in changes of fire-killed western larch. While most wood borers prefer recently killed trees, some will infest live trees in areas adjacent to burn sites (Werner 2002). Highest risk for wood borer infestation within and around burned areas usually occurs the first year after a disturbance; populations decrease significantly afterward (Werner and Post 1985). Werner (2002) caught fewer wood borers with progressing years in a burned area of white spruce, but continued capturing the same species ten years after fire as he caught in the first few years post-fire. Larvae of the whitespotted sawyer, *Monochamus scutellatus* Say, sometimes require three years to develop, penetrate deep into the sapwood and cause extensive damage (Cerezke 1975).

METHODS

Year 2 Data Collection

Standing Tree Evaluations

Forty of the original 367 study trees had been dissected in fall 2002. In late May 2003, the 327 trees that remained standing were observed to determine if they were living and which had sloughed bark, woodpecker foraging, or fungal conks.

Adult Wood- and Bark-Boring Insect Collection and Identification

Wood- and bark-boring insects were collected using two methods: (1) emergence traps placed on standing trees, and (2) bolts collected from trees that were dissected and identified as infested in fall 2002.

Since most trees were not to be felled until a later date - and most wood borers usually infest trees one to two years after disturbance - traps were used to capture some insects as they emerged from standing trees. In late April 2003, one trap was placed on the north side of a standing tree in each of the four size classes at each of the five sites for a total of twenty traps. Trap development and methodology for this project was based on information from other studies (Werner 2003, Werner 2002, Post and Werner 1988, and Vallentgoed 1991). Emergence traps were made of soft-mesh screening, 30 cm wide by 60 cm tall. Mesh perimeter was underlined with a one-inch wide by one-half-inch-thick strip of foam; stapled to the tree. A collection cup containing a one-inch by one-inch piece of No-Pest® Strip was placed at the trap's base by cutting an 'X' in the mesh, placing the cup's mouth inside the mesh, and taping the mesh flaps to the outside surface of cup with duct tape. Insects were collected from traps while conducting tree dissections in late September and early October. All insects were bagged and frozen for later identification.

Fourteen bolts were gathered from the field in April 2003. Each 18-inch-long bolt was collected from a felled tree identified as heavily infested during 2002 dissections via observations of larvae and wood borer-caused holes. They were taken at various heights in trees at all five sites and included trees of all size classes. Insects were reared by placing bolts in metal cans covered with a mesh. Bolts were stored in a non-climate-controlled warehouse. Insects were collected from cans in autumn 2003. All insects were bagged and frozen for later identification.

Agent and Scaling Data

From September 29 through October 10, 2003, ten trees were dissected in each size class. Agent and scaling data were collected from each tree. Given variability in feller skill, breakage was not included in defects described in this report. Loss to breakage should be included in estimates of total merchantable volume.

Year 3 Data Collection

Agent and Scaling Data

From September 7 through September 24, 2004, ten trees were dissected in each size class with agent and scaling data collected. Tree number 662 may have been dead prior to the Moose Fire as evidenced by many, older-appearing checks. Given variability in feller skill, breakage was not included in defects described in this report. Loss to breakage should be included in estimates of total merchantable volume.

Combined Agent and Scaling Data for the First 3 Years

For purpose of illustrating agent progress and reduced merchantable volume over the first three years post-fire, and to contrast differences between size classes, means for each size class were compiled into three tables (Tables 6, 7, and 8).

Year 4 Data Collection

Standing Tree Evaluations

In June 2005, all trees tagged in 2002 and not yet dissected were observed to determine if they were dead, standing, had broken tops, sloughed bark, or conks present. Bark was considered "sloughed" when exposed wood could be seen as a result of separation of bark from wood and not caused by woodpecker foraging or rubbing from nearby fallen trees. When conks were observed, fungal species and location of conks were also noted.

Precipitation Data Collection

After observing an apparent reduction in number and size of checks in year three disks compared to year two disks, precipitation data was taken from the Western Regional Climate Center's web page (www.wrcc.dri.edu/index.html) to compare three months (July through September 2003 and June through August 2004) preceding data collection. Data used came from the West Glacier, Montana (248809) weather station located approximately 10 to 15 miles southeast of study sites and 3,150 feet elevation (approximately 500 to 1,100 feet lower than study sites).

RESULTS

Year 2

Evaluation of All Standing Trees

Of 367 trees identified and tagged for this study, 40 trees had been dissected in fall 2002. Three hundred twenty-seven remained since no trees had fallen due to natural causes. Fourteen (4%) of the 327 trees thought to be dead in June 2002, still had green shoots, albeit minimal, in May 2003. Nine trees with green shoots were on site four, two were on site three, two were on site two, and one was on site one. No trees had broken tops post- fire. Twenty-one (6%) of the 327 trees had sloughing bark, with most sloughing on the uphill side. One tree (#648) contained two *Cryptoporus volvatus* (Pk.) Shear conks about 12 feet off the ground. No other conks were observed on standing trees.

Adult Wood- and Bark-Boring Insect Collection and Identification

Bolts yielded more insects than traps. The combination of insects captured by emergence traps and bolts resulted in a variety of species. Wood- and bark-boring insects found are shown in Table 1.

Table 1. Wood- and Bark-Boring Insects Collected Two Years Post-Fire.

Family	Species
Cerambycidae	*Tetropium velutinum* LeConte
	Rhagium inquisitor L.
	Xylotrechus longitarsus Casey
	Monochamus scutellatus Say
	Spondylis upiformis Mannerheim
Buprestidae	*Melanophila drummondi* Kirby
Siricidae	*Sirex cyaneus* F.
Scolytidae	*Dendroctonus pseudotsugae* Hopkins
	Trypodendron lineatum Olivier
	Scolytus laricis Blackman

Agent and Scaling Data

All 40 trees scheduled for dissection were still standing immediately prior to dissection. One tree (#641) contained two fruiting bodies of the sapwood decay fungus *C. volvatus*. These fruiting bodies were not observed during the evaluation of all standing trees four months earlier. No post-fire broken tops were observed. Five (13%) showed evidence of bark sloughing on boles. All trees showed evidence of woodpecker foraging.

Of six attempts to isolate fungi from sapwood decay, *Stereum sanguinolentum* and a *Ganoderma* sp. were each retrieved from an individual tree. Although isolation was attempted, no basidiomycete was isolated from the tree (#641) that contained *C. volvatus* conks.

Agent and scaling data derived from dissections are summarized for each tree and size class in Tables 2 and 3 and for disk height in Figure 1.

Table 2. Agent Data Summarized by Tree Two Years After the Moose Fire

Tree No.	DBH[A] (inches)	Age[B] (Years)	Site[C]	Deepest Borers[D] (mm)	Borer Holes/Sq. Foot[E]	Stain[F] (Percent)	Sapwood Decay[G] (Percent)	Deepest Check[H] (mm)	No. of Checks[I]	Sapwood Volume (Percent)[J]
531	8.3	77	1	52	11.0	6.5	1.0	37	0.9	34.9
602	8.6	84	1	51	6.5	7.6	0.3	62	1.5	46.1
901	8.9	87	5	10	0.6	4.9	0	80	1.7	59.8
553	9.3	85	1	32	1.5	10.6	0	67	1.4	45.2
514	9.7	90	1	51	24.1	14.8	1.5	54	1.9	41.7
925	10.1	84	5	43	0.4	3.5	0	72	0.4	43.6
582	10.5	-[K]	3	50	6.4	3.2	2.5	76	1.5	33.6
587	11.5	85	3	73	6.5	2.4	0.7	70	6.0	35.9
622	11.8	77	1	79	17.8	10.6	0.6	39	0.2	42.4
969	12	177	5	0	1.7	4.7	0	70	1.9	21.2
MDC[L]	10.1	94	-	49	7.7	6.9	0.7	62.7	1.7	40.4
954	12.3	86	4	9	0.2	1.6	0	85	1.4	44.5
727	12.4	171	3	28	1.8	7.1	0	47	3.7	38.4
685	12.7	226	1	36	1.9	1.2	0	170	1.7	33.2
557	13	86	4	60	10.4	3.9	0.6	56	1.0	38.8
711	14	232	4	18	1.8	7.1	0	52	3.6	27.9
736	14.3	228	1	30	1.8	3.0	0	40	2.7	22.5
512	14.6	90	1	61	16.8	11.1	2.8	67	0.7	32.4
641	14.9	79	5	52	5.6	5.4	0.9	44	0.7	39.1
964	15.5	215	3	27	0.3	3.2	0	105	4.0	17.7
672	15.7	194	4	27	5.3	6.2	0	20	0.4	35.2
MDC	13.9	161	-	34.8	4.6	5.0	0.4	68.6	2.0	33.0
924	16.2	232	5	36	1.6	1.7	0	38	1.4	29.2
511	16.8	87	1	55	15.3	5.2	0.9	50	0.7	31.4
753	17.3	224	4	32	0.6	0.3	0.3	130	4.9	19.7
687	17.6	197	3	39	2.8	4.5	0.6	122	4.8	23.8
905	18	196	5	32	0.7	0.5	0	45	1.3	24.7
793	18.2	205	5	40	2.1	2.4	0	0	0	32.8
600	18.6	225	3	21	3.1	2.2	0.6	22	0.3	25.9
756	19.1	-[K]	4	58	1.5	1.2	0.5	105	7.6	16.7
950	19.5	224	5	39	1.6	3.3	0	70	5.4	23.8
597	19.8	230	3	53	1.6	6.1	0.1	87	2.7	27.7
MDC	18.1	202	-	40.5	3.1	2.7	0.3	66.9	2.9	25.6
668	20.8	176	3	86	1.9	1.6	0.1	50	5.3	14.4
676	21.1	196	3	35	1.3	4.3	1.2	50	3.4	28.6
691	22	219	3	33	1.9	1.7	0.4	50	4.4	20.1
902	23	210	5	94	3.0	4.7	0.3	39	1.6	28.1
699	23.7	234	4	115	1.4	2.2	2.2	80	7.5	14.9
564	24.3	232	2	46	3.5	3.1	0.4	47	4.9	14.9
918	25.3	220	5	52	1.2	1.3	4.7	64	3.0	21.7
731	26.8	204	4	30	1.9	4.6	0	85	4.5	15.7
779	28.2	219	4	65	1.8	2.6	0.1	95	17.1	16.7
764	29.1	234	4	60	2.3	0.9	1.6	53	7.7	17.2
MDC	24.4	214	-	61.6	2.0	2.7	1.1	61.3	5.9	19.2

See legend on page 6.

Legend for Table 2 and Table 4.

[A]Diameter at breast height (4.5 feet above ground level).

[B]Age-estimated by counting annual rings at the stump.

[C] Tree location (see Jackson 2004).

[D]Distance of wood borer hole that was furthest from the edge of wood on any disk from the tree.

[E]Wood borers - average number of wood borer holes per square foot of disk area observed.

[F]Estimated percent cubic volume affected by sapwood stain. Estimated by calculating volume of each log using Smalian's Formula for a paraboloid frustum and multiplying total volume of the log by the mean of percent area affected by sapwood stain on disk at each end of the log. Total stain volume in the tree was then divided by total tree volume.

[G]Estimated percent cubic volume affected by sapwood decay. Estimated by calculating volume of each log using Smalian's Formula for a paraboloid frustum and multiplying total volume of the log by the mean of percent area affected by sapwood decay on disk at each end of the log. Total sapwood decay volume in the tree was then divided by total tree volume.

[H]Depth of deepest check found on any disk from the tree.

[I]Quotient when total number of peripheral checks on all disks are divided by total number of disks on that tree.

[J]Percent sapwood volume estimated by calculating total volume of each log and heartwood volume of each log using Smalian's Formula for a paraboloid frustum. Heartwood volume was then subtracted from total volume, with the difference divided by total volume and multiplied by 100.

[K]Data not taken.

[L]MDC - mean for diameter class. Mean for the ten values in diameter class.

Table 3. Scaling Data Summarized by Tree Two Years After the Moose Fire

			Scribner Rule (Board Feet)				Cubic Rule (Cubic Feet)			
Tree No.	DBH[A] (Inches)	Age[B] (Years)	Pre-existing Defect[C]	Post-Fire Defect[D]	Total Scaler Defect[E]	Gross Scaler Vol. [F]	Pre-existing Defect[G]	Post-Fire Defect[H]	Total Scaler Defect[I]	Gross Scaler Vol.[J]
531	8.3	77	0	10	10	50	0	4.8	4.8	13.2
602	8.6	84	0	0	0	50	0.7	5.6	6.3	14.3
901	8.9	87	0	0	0	40	2.7	2.5	5.2	12.3
553	9.3	85	0	0	0	40	0.7	1.2	1.9	11.6
514	9.7	90	10	10	20	60	0.2	5.6	5.8	17.2
925	10.1	84	0	0	0	70	0	0.7	0.7	19.1
582	10.5	-[K]	10	30	40	50	1	7.8	8.8	15.4
587	11.5	85	20	10	30	60	5.2	6.0	11.2	15.9
622	11.8	77	0	50	50	100	0	9.5	9.5	22.7
969	12	177	10	0	10	70	3.2	3.3	6.5	19.4
MDC[L]	10.1	94	5	11	16	59	1.4	4.7	6.1	16.1
954	12.3	86	10	0	10	110	2.6	2.9	5.5	24.6
727	12.4	171	10	10	20	50	4.0	2.0	6.0	15.2
685	12.7	226	20	30	50	170	8.9	1.5	10.4	32.0
557	13	86	0	50	50	170	0	6.5	6.5	33.6
711	14	232	0	0	0	170	0	2.7	2.7	36.2
736	14.3	228	30	0	30	190	9.6	0	9.6	37.8
512	14.6	90	70	60	130	210	3.7	9.4	13.1	40.9
641	14.9	79	0	10	10	200	0	4.8	4.8	38.4
964	15.5	215	10	60	70	210	1.6	8.1	9.7	39.7
672	15.7	194	50	0	50	230	16.2	0.3	16.5	44.7
MDC	13.9	161	20	22	42	171	4.7	3.8	8.5	34.3
924	16.2	232	10	0	10	250	2.4	1.1	3.5	46.7
511	16.8	87	0	70	70	300	0	12.9	12.9	55.2
753	17.3	224	40	20	60	280	5.4	6.2	11.6	51.8
687	17.6	197	50	20	70	280	13.3	1.7	15.0	51.6
905	18	196	20	40	60	290	3.5	5.1	8.6	50.3
793	18.2	205	20	10	30	310	3.3	1.7	5.0	54.2
600	18.6	225	40	20	60	330	9.7	2.1	11.8	56.8
756	19.1	-	80	10	90	460	7.5	3.2	10.7	79.1
950	19.5	224	50	0	50	390	3.5	0.7	4.2	66.8
597	19.8	230	60	30	90	450	4.2	4.2	8.4	75.4
MDC	18.1	202	37	22	59	334	5.3	3.9	9.2	58.8
668	20.8	176	480	0	480	480	81.1	0	81.1	81.1
676	21.1	196	50	90	140	490	5.5	9	14.5	79.2
691	22	219	70	30	100	580	4.6	7.3	11.9	94.0
902	23	210	180	0	180	520	16.9	0.5	17.4	85.7
699	23.7	234	100	110	210	720	6.3	15.5	21.8	112.0
564	24.3	232	150	50	200	840	10.9	7.6	18.5	127.9
918	25.3	220	610	0	610	610	97.1	0	97.1	97.1
731	26.8	204	90	10	100	790	9.0	1.4	10.4	122.0
779	28.2	219	320	0	320	1390	31	2.1	33.1	197.1
764	29.1	234	530	0	530	1500	73.3	0	73.3	210.3
MDC	24.4	214	258	29	287	792	33.6	4.3	37.9	120.6
Total	-	-	3200	840	4040	13560	448.8	167.5	616.3	2298.5

See legend on page 8.

Legend for Table 3, Table 5, Table 7, and Table 8.

[A]Diameter at breast height (4.5 feet above ground level).

[B]Age-estimated by observing annual rings at the stump.

[C]Number of board feet deducted from tree volume due to pre-existing defects such as crook, heart shake, heartwood decay, etc.

[D]Number of board feet deducted from tree volume due to post-fire defects such as peripheral checks, wood borers, and sapwood decay.

[E]Total number of board feet deducted from tree volumes due to both pre-existing and post-fire defects.

[F]Total number of board feet in tree at time of dissection.

[G]Cubic volume deducted from tree due to pre-existing defects such as crook, heart shake, heartwood decay, etc.

[H]Cubic volume deducted from tree due to post-fire defects such as peripheral checks, wood borers, and sapwood decay.

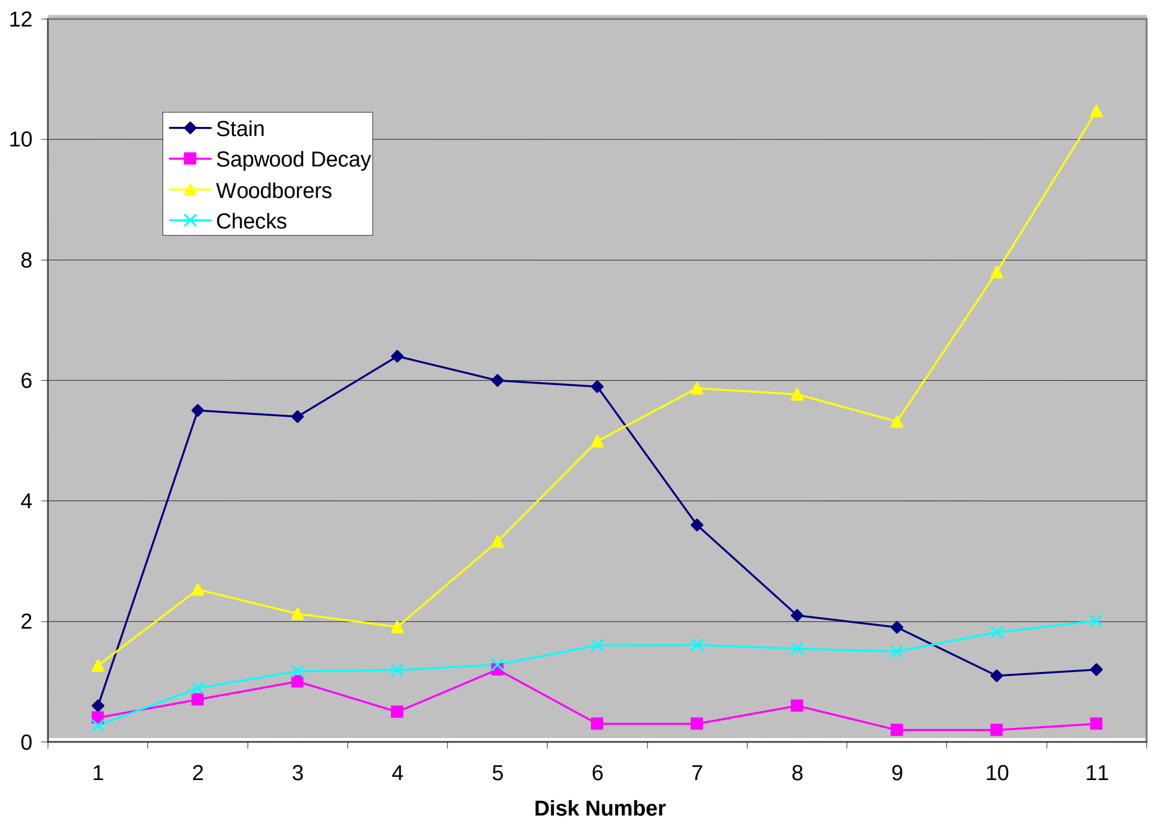
[I]Cubic volume deducted from tree due to both pre-existing and post-fire defects.

[J]Total cubic volume in the tree at time of dissection.

[K]Data not taken.

[L]MDC - mean for the diameter class.

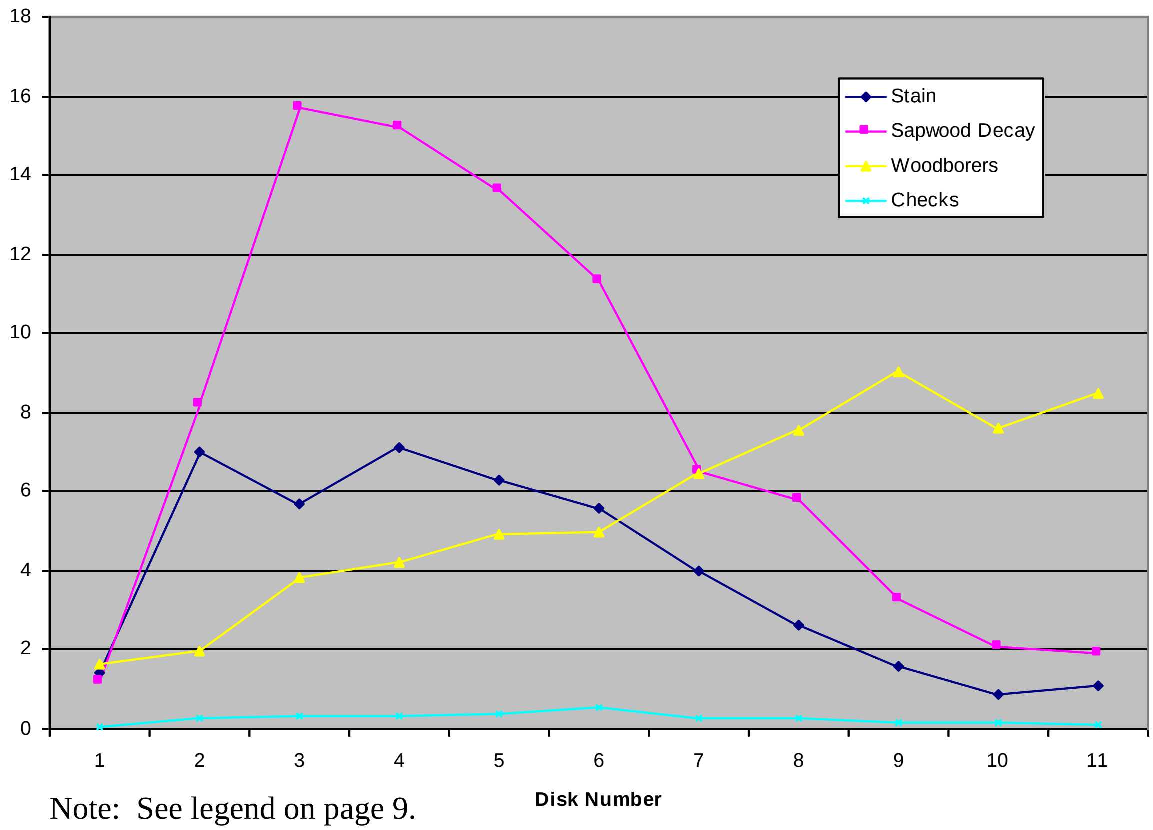
Figure 1. Agents at Different Heights (Year 2)



Legend for Figures 1 and 2

*Disk number identifies distance from ground level while tree was standing. Disk 1 = 1 to 2 feet above ground level. Every subsequent disk height = (8 X Disk Number - 6 to 7) (eg. disk seven was 49 to 50 feet from ground level). There were 40 disks for each disk number of one through six for both years and progressively less disks for each higher number in both years. Disk eleven was the highest disk used, since disk twelve and above consisted of less than 20 disks.
*"Stain" is the mean percent of total surface area affected.
*"Sapwood Decay" is the mean percent of total surface area affected.
*"Woodborers" refers to number of woodborers per square foot on disk surface.
*"Checks" refers to number of checks per foot of disk circumference.

Figure 2. Agents at Different Heights (Year 3)



Note: See legend on page 9.

Year 3

Agent and Scaling Data

All 40 trees scheduled for dissection were still standing. Seven (18%) contained fruiting bodies of decay-causing fungi. Four trees contained *Fomitposis pinicola* (Swartz:Fr.) Karst., two contained *C. volvatus*, and one tree (#633) contained both *F. pinicola* and *C. volvatus* fruiting bodies. Four (10%) trees had post-fire broken tops. Five (13%) of the 40 trees showed evidence of bark sloughing on boles. All trees showed evidence of woodpecker foraging.

Of 61 attempts to isolate fungi from sapwood decay, 39 yielded apparent basidiomycetes. Only ten isolates were submitted to the Forest Products Laboratory since most of them appeared very similar in culture and decay characteristics. Of the ten isolates, seven were identified as *F. pinicola*, one as *S. sanguinolentum*, and two were not identified. Prior to submitting cultures for identification, isolates were grouped according to gross cultural similarities. *F. pinicola* isolates represented 36 isolates, *S. sanguinolentum* represented one isolate, one unidentified isolate represented two isolates, and the other unidentified isolate came from a group that included one of seven *F. pinicola* isolates.

Agent and scaling data derived from dissections are summarized for each tree and size class in Tables 4 and 5 and disk height in Figure 2.

Table 4. Agent Data Summarized by Tree Three Years After the Moose Fire

Tree No.	DBH[A] (inches)	Age[B] (Years)	Site[C]	Deepest Borers[D] (mm)	Borer Holes/Sq. Foot[E]	Stain[F] (Percent)	Sapwood Decay[G] (Percent)	Deepest Check[H] (mm)	No. of Checks[I]	Sapwood Volume (Percent)[J]
562	8.3	80	1	25	2.1	5.6	8.0	15	0.1	42.2
521	8.6	100	1	64	17.2	6.4	16.7	37	0.7	46.8
526	8.9	80	1	61	14.3	0.6	34.5	19	0.5	43.0
532	9.1	81	1	40	9.8	2.4	24.9	61	0.8	45.1
552	9.7	78	1	30	9.8	8.7	23.9	15	0.1	43.4
507	10.5	80	1	52	10.6	1.5	12.0	0	0	40.8
585	10.9	82	3	28	7.3	0.6	5.6	0	0	44.4
556	11.3	90	1	47	3.2	14.4	1.0	90	1.4	34.3
542	11.7	84	1	74	17.8	6.6	26.5	61	0.3	40.1
551	11.9	85	1	55	3.3	14.0	1.7	75	2.8	43.2
MDC[L]	10.1	84	-	47.6	9.5	6.1	15.5	46.6	0.7	42.3
738	12.1	210	4	30	2.4	0.5	12.6	0	0	30.6
967	12.7	194	5	21	0.2	4.4	1.2	87	1.5	36.5
636	12.9	82	1	50	9.2	3.3	18.4	0	0	44.8
916	13.5	154	5	34	3.3	19.4	5.2	40	0.6	39.6
629	13.9	80	1	51	9.7	4.8	19.0	57	1.6	36.1
702	14.2	195	4	85	7.3	2.8	0.4	10	0.3	20.9
737	14.8	197	4	65	4.2	2.0	7.9	55	0.7	31.6
541	15.4	85	1	88	13.6	4.6	15.1	65	1.1	32.5
957	15.4	203	5	47	1.5	8.3	5.2	63	0.6	26.3
670	15.6	198	3	57	6.4	2.3	3.7	0	0	26.3
MDC	14.1	160	-	52.8	5.8	5.2	8.9	53.9	0.6	32.5
743	16.3	208	4	38	2.4	3.6	6.1	0	0	22.1
945	16.9	204	5	64	5.0	2.9	14.4	18	0.1	28.2
958	17.3	166	5	67	6.9	3.4	8.2	0	0	30.0
662	17.5	135	3	8	0.4	2.4	0.2	118	2.1	13.7
772	17.8	-[K]	4	43	2.7	4.7	6.1	18	0.3	22.6
633	18.2	85	1	50	4.0	0.4	22.3	0	0	30.5
717	18.7	243	4	75	5.6	7.1	4.1	85	4.8	26.9
966	19.2	223	5	38	2.1	3.1	16.0	34	0.2	28.3
675	19.4	213	3	70	3.5	3.1	6.2	0	0	29.1
679	19.7	215	3	40	3.3	1.1	4.6	25	0.1	29.2
MDC	18.1	188	-	49.3	3.6	3.2	8.8	49.7	0.8	26.0
589	20.4	200	3	39	1.6	5.5	7.7	15	0.3	28.8
800	20.7	196	5	48	3.0	7.6	1.6	42	0.9	24.0
721	21.1	204	4	107	3.3	2.7	5.9	23	2.1	23.8
792	22.2	210	5	77	5.5	3.7	1.9	0	0	20.5
728	22.8	225	4	75	2.7	6.5	4.6	70	1.4	19.6
791	23.7	216	5	45	3.5	12.1	5.0	0	0	24.5
798	23.8	220	5	50	3.2	6.3	6.0	31	0.1	22.1
663	24.8	206	3	65	4.9	1.6	3.6	0	0	21.7
795	26	210	5	35	2.3	2.1	10.3	17	0.4	20.9
719	28.6	225	4	85	3.2	1.7	4.4	43	1.2	22.7
MDC	23.4	211	-	62.6	3.3	5.0	5.1	34.4	0.6	22.9

See legend on page 6.

Table 5. Scaling Data Summarized by Tree Three Years After the Moose Fire

			Scribner Rule (Board Feet)				Cubic Rule (Cubic Feet)			
Tree No.	DBH[A] (inches)	Age[B]	Pre-existing Defect[C]	Post-Fire Defect[D]	Total Scaler Defect[E]	Gross Scaler Vol.[F]	Pre-existing Defect[G]	Post-Fire Defect[H]	Total Scaler Defect[I]	Gross Scaler Vol.[J]
562	8.3	80	0	40	40	40	0	9.2	9.2	10.3
521	8.6	100	0	30	30	40	0.4	8.7	9.1	11.5
526	8.9	80	0	40	40	60	0	8.9	8.9	14.1
532	9.1	81	0	30	30	50	0	7.5	7.5	13.5
552	9.7	78	0	30	30	50	0	7.2	7.2	14.0
507	10.5	80	0	40	40	90	0	9.7	9.7	20.4
585	10.9	82	0	10	10	50	0.5	6.0	6.5	13.7
556	11.3	90	0	10	10	80	0	1.5	1.5	20.5
542	11.7	84	0	60	60	110	0	14.4	14.4	24.4
551	11.9	85	0	10	10	120	0	0.7	0.7	24.9
MDC[L]	10.1	84	0	30	30	69	0.1	7.4	7.5	16.7
738	12.1	210	0	40	40	140	0	6.8	6.8	28.1
967	12.7	194	20	20	40	180	3.6	2.5	6.1	36.0
636	12.9	82	0	50	50	100	0	9.4	9.4	24.0
916	13.5	154	20	50	70	160	3.0	6.4	9.4	32.0
629	13.9	80	0	70	70	170	0	12.5	12.5	34.5
702	14.2	195	140	0	140	160	28.6	0	28.6	33.5
737	14.8	197	0	50	50	240	2.0	5.0	7.0	46.2
541	15.4	85	10	120	130	240	0.6	24.4	25.0	44.4
957	15.4	203	60	60	120	270	11.0	7.4	18.4	49.2
670	15.6	198	100	20	120	220	18.8	3.6	22.4	41.4
MDC	14.1	160	35	48	83	188	6.8	7.8	14.6	36.9
743	16.3	208	20	30	50	260	0.8	9.6	10.4	50.4
945	16.9	204	20	80	100	320	4.9	10.5	15.4	55.7
958	17.3	166	60	80	140	310	10.1	11.4	21.5	54.8
662	17.5	135	10	200	210	320	0.9	31.8	32.7	57.8
772	17.8	-[K]	20	50	70	270	1.8	7.8	9.6	50.4
633	18.2	85	0	100	100	310	0	15.1	15.1	54.2
717	18.7	243	0	120	120	500	0.3	15.3	15.6	82.0
966	19.2	223	50	120	170	480	7.6	17.3	24.9	80.4
675	19.4	213	270	90	360	470	47.8	13	60.8	79.8
679	19.7	215	10	70	80	440	1.0	8.6	9.6	74.3
MDC	18.1	188	46	94	140	368	7.5	14.0	21.6	64.0
589	20.4	200	70	120	190	500	11.2	14.5	25.7	81.2
800	20.7	196	30	20	50	510	0.9	1.5	2.4	83.8
721	21.1	204	10	100	110	450	0.7	12.7	13.4	79.2
792	22.2	210	60	10	70	440	2.9	1.2	4.1	74.4
728	22.8	225	80	60	140	780	6.2	7.9	14.1	120.7
791	23.7	216	90	90	180	600	15.9	13.5	29.4	98.2
798	23.8	220	10	90	100	760	0.4	14.7	15.1	118.0
663	24.8	206	90	170	260	740	19.4	20.8	40.2	119.0
795	26	210	20	90	110	660	1.4	11.9	13.3	106.4
719	28.6	225	80	160	240	1480	6.0	19.7	25.7	207.2
MDC	23.4	211	54	91	145	692	6.5	11.8	18.3	108.8
Total	-	-	1350	2630	3980	13170	208.7	410.6	619.3	2264.5

See legend of page 8.

<u>Combined Agent and Scaling Data for the First Three Years</u>

Table 6. Agent Data Means Summarized by Size Class and Year

Size Class	Year[A]	DBH[B] (Inches)	Deepest Borers[C] (mm)	Borer Holes/Sq. Foot[D]	Borer Holes/ Disk[E]	Stain[F] (Percent)	Sapwood Decay[G] (Percent)	Deepest Check[H] (mm)	No. of Checks[I]	Sapwood Volume (Percent)[J]
8-11.9	1	10.0	29.4	2.6	0.8	2.7	0	N/A[K]	0	-[L]
8-11.9	2	10.1	49	7.7	2.5	6.9	0.7	62.7	1.7	40.4
8-11.9	3	10.1	47.6	9.5	3.0	6.1	15.5	46.6	0.7	42.3
8-11.9	All Years	10.0	44.3	6.6	2.0	5.2	5.4	55.6	0.8	41.4
12-15.9	1	14.1	26.7	2.3	1.0	3.0	0	N/A[K]	0	-[L]
12-15.9	2	13.9	34.8	4.6	2.3	5.0	0.4	68.6	2.0	33.0
12-15.9	3	14.1	52.8	5.8	3.0	5.2	8.9	53.9	0.6	32.5
12-15.9	All Years	14.0	39.4	4.2	2.1	4.4	3.1	62.5	0.9	32.7
16-19.9	1	18.0	43.1	2.3	1.5	1.2	0	N/A[K]	0	-[L]
16-19.9	2	18.1	40.5	3.1	2.1	2.7	0.3	66.9	2.9	25.6
16-19.9	3	18.1	49.3	3.6	2.9	3.2	8.8	49.7	0.8	26.0
16-19.9	All Years	18.1	44.3	3.0	2.2	2.4	3.0	64.5	1.2	25.8
20+	1	24.9	30	0.8	0.9	0.5	0.7	N/A[K]	0	-[L]
20+	2	24.4	61.6	2.0	2.4	2.7	1.1	61.3	5.9	19.2
20+	3	23.4	62.6	3.3	3.6	5.0	5.1	34.4	0.6	22.9
20+	All Years	24.2	54.7	2.0	2.3	2.7	2.3	50.2	2.2	21.0
All Sizes	1	16.7	33.4	2.0	1.1	1.8	0.1	N/A[K]	0	-[L]
All Sizes	2	16.6	46.4	4.4	2.3	4.3	0.6	66.5	3.1	29.6
All Sizes	3	16.4	53.1	5.6	3.1	4.9	9.6	46.0	0.7	31.0
All Sizes	All Years	16.6	45.6	4.0	2.2	3.7	3.4	58.0	1.3	30.2

Note: Each non-shaded row consists of means derived from all ten trees for size class and year. "All Years" are means derived from all 30 trees for each size class. "All Sizes" are means derived from all 40 trees each year.

Superscipts denote how data was derived for each tree used in the means of the table.

[A]Number of years after fire.

[B]Diameter at breast height (4.5 feet above ground level).

[C]Distance of wood borer hole that was furthest from the edge of wood on any disk from the tree.

[D]Wood borers - average number of wood borer holes per square foot of disk area observed.

[E]Wood borers - average number of wood borer holes per disk.

[F]Estimated percent cubic volume affected by sapwood stain. Estimated by calculating the volume of each log using Smalian's Formula for a paraboloid frustum and multiplying the total volume of the log by the mean of the percent area affected by sapwood stain on the disk at each end of the log. The total stain volume in the tree was then divided by the total tree volume.

[G]Estimated percent cubic volume affected by sapwood decay. Estimated by calculating the volume of each log using Smalian's Formula for a paraboloid frustum and multiplying the total volume of the log by the mean of the percent area affected by sapwood decay on the disk at each end of the log. The total sapwood decay volume in the tree was then divided by the total tree volume.

[H]Depth of the deepest check found on any disk from the tree.

[I]Quotient when the total number of peripheral checks on all disks is divided by the total number of disks on that tree.

[J]Percent sapwood volume estimated by calculating the total volume of each log and the heartwood volume of each log using Smalian's Formula for a paraboloid frustum. The heartwood volume was then subtracted from the total volume, with the difference divided by the total volume and multiplied by 100.

[K]Check depth is not applicable since no checks were observed in the first year.

[L]Data not taken.

Table 7. Scaling Data Means Summarized by Size Class and Year

Size Class	Year*	DBH[A] (Inches)	Age[B] (Years)	Scribner Rule (Board Feet) Pre-existing Defect[C]	Post-fire Defect[D]	Total Scaler Defect[E]	Gross Scaler Vol.[F]	Cubic Rule (Cubic Feet) Pre-existing Defect[G]	Post-fire Defect[H]	Total Scaler Defect[I]	Gross Scaler Vol.[J]
8-11.9	1	10.0	82.4	0	0	0	62	0.4	0.2	0.6	16.2
8-11.9	2	10.1	94	5	11	16	59	1.4	4.7	6.1	16.1
8-11.9	3	10.1	84	0	30	30	69	0.1	7.4	7.5	16.7
8-11.9	All	10.0	86.6	1.7	13.7	15.3	63.3	0.6	4.1	4.7	16.3
12-15.9	1	14.1	137.3	11	1	12	187	1.2	0.6	1.8	36.6
12-15.9	2	13.9	161	20	22	42	171	4.7	3.8	8.5	34.3
12-15.9	3	14.1	159.8	35	48	83	188	6.8	7.8	14.6	36.9
12-15.9	All	14.0	152.6	22	23.7	45.7	182	4.2	4.1	8.3	35.9
16-19.9	1	18.0	180	37	2	39	355	4.2	0.8	5.0	61.8
16-19.9	2	18.1	202	37	22	59	334	5.3	3.9	9.2	58.8
16-19.9	3	18.1	188	46	94	140	368	7.5	14.0	21.6	64.0
16-19.9	All	18.1	189.7	40	39.3	79.3	352.3	5.7	6.2	11.9	61.5
20+	1	24.9	201.5	182	0	182	718	23.8	0.1	23.9	114.2
20+	2	24.4	214	258	29	287	792	33.6	4.3	37.9	120.6
20+	3	23.4	211.2	54	91	145	692	6.5	11.8	18.3	108.8
20+	All	24.2	209.0	164.7	40	204.7	734	21.3	5.4	26.7	114.5
All Sizes	1	16.7	150.3	57.5	0.75	58.3	330.5	7.4	0.4	7.8	57.2
All Sizes	2	16.6	168.9	80	21	101	339	11.2	4.2	15.4	57.5
All Sizes	3	16.4	160.1	33.8	65.8	99.5	329.3	5.2	10.3	15.5	56.6
All Sizes	All	16.6	159.6	57.1	29.2	86.3	332.9	7.9	5.0	12.9	57.1

Note: Each non-shaded row consists of means derived from all ten trees for the size class and year. "All" years are means derived from using all 30 trees for each size class. "All Sizes" are means derived by using all 40 trees from each year.

*Number of years after the fire.

See page 8 for legend.

Table 8. Percent Scaling Data Means Summarized by Size Class and Year

				Scribner Rule (Board Feet)				Cubic Rule (Cubic Feet)			
Size Class	Year*	DBH[A] (Inches)	Age[B] (Years)	Pre-existing Defect	Post-fire Defect	Total Scaler Defect	Gross Scaler Vol.[F]	Pre-existing Defect	Post-fire Defect	Total Scaler Defect	Gross Scaler Vol.[J]
8-11.9	1	10.0	82.4	0	0	0	62	3.0	1.3	4.4	16.2
8-11.9	2	10.1	94	8.4	16.3	24.8	59	9.0	29.0	37.9	16.1
8-11.9	3	10.1	84	0	50.1	50.1	69	0.7	49.6	50.3	16.7
8-11.9	All	10.0	86.6	2.8	22.2	25.0	63.3	4.2	26.6	30.9	16.3
12-15.9	1	14.1	137.3	7.0	1.0	8.0	187	3.3	2.8	6.0	36.6
12-15.9	2	13.9	161	11.6	12.9	24.6	171	13.9	11.3	25.2	34.3
12-15.9	3	14.1	159.8	18.3	26.4	44.7	188	17.8	21.6	39.4	36.9
12-15.9	All	14.0	152.6	12.3	13.4	25.8	182	11.7	11.9	23.6	35.9
16-19.9	1	18.0	180	9.6	0.7	10.3	355	6.3	1.6	7.8	61.8
16-19.9	2	18.1	202	10.5	7.0	17.5	334	9.2	6.9	16.0	58.8
16-19.9	3	18.1	188	11.4	26.0	37.4	368	10.5	22.5	33.0	64.0
16-19.9	All	18.1	189.7	10.5	11.2	21.7	352.3	8.6	10.3	19.0	61.5
20+	1	24.9	201.5	25.2	0	25.2	718	20.2	0.1	20.2	114.2
20+	2	24.4	214	35.8	4.6	40.4	792	30.4	4.2	34.5	120.6
20+	3	23.4	211.2	8.3	13.4	21.7	692	6.2	10.8	17.0	108.8
20+	All	24.2	209.0	23.1	6.0	29.1	734	18.9	5.0	23.9	114.5
All Sizes	1	16.7	150.3	10.4	0.4	10.9	330.5	8.2	1.4	9.6	57.2
All Sizes	2	16.6	168.9	16.6	10.2	26.8	339	15.6	12.8	28.4	57.5
All Sizes	3	16.4	160.1	9.5	29.0	38.5	329.3	8.8	26.1	34.9	56.6
All Sizes	All	16.6	159.6	12.2	13.2	25.4	332.9	10.9	13.5	24.3	57.1

Note: In each non-shaded row, defect categories ("Pre-existing;" "Post-fire," and "Total Scaler") are means of percents gross volume affected for the ten trees in each year and size class. "All" years are means derived from using all 30 trees for each size class. "All Sizes" are means derived from using all 40 trees each year.

*Number of years after the fire.

See legend on page 8 for superscripts A, B, F, and J.

Year 4

Evaluation of All Standing Trees

Four years after the fire, no trees had fallen due to natural causes. Of the original 367 trees identified and tagged, one was removed from the data set because it was a Douglas-fir, one was lost to firewood cutters, 120 had been dissected, and the remaining 245 were still standing. All trees were dead four years post-fire. Twenty-two (9%) of the 245 standing trees had broken tops. Seventy-nine (32%) of the standing trees had sloughing bark. One hundred-nine (44%) of the standing trees contained fruiting bodies of decay-causing fungi. Ninety-four trees contained *F. pinicola*, seven contained *Trichaptum abietinum* (Dickson:Fr.) Ryvarden, five contained *C. volvatus*, and one contained *Gleophyllum sepiarium* (Wulfen:Fr.) P. Karst. conks. Two trees had both *F. pinicola* and *C. volvatus* conks and one tree (#648) contained *F. pinicola*, *C. volvatus*, and *T. abietinum* conks.

Precipitation

The West Glacier Weather Station showed 2.07 inches of precipitation occurred from July through September 2003 and 9.08 inches of precipitation occurred from June through August 2004.

DISCUSSION

Agents of Change

Wood Borers

Although there does not appear to be any difference in wood-boring insect depth across size classes, wood borers generally worked deeper into the wood over time (Table 6). This is especially evident when comparing one and three years post-fire. The number of wood borer holes found per disk during dissections increased each year within all size classes. Higher numbers of insect-caused holes in disks in subsequent years of this study may be a result of a combination of continued feeding by those insects already present, increasing the chance of detection as their tunnels reach more of the wood, and infestations by insects, same or different species, that weren't present in earlier years.

Although there were slightly more wood borer holes in the disks of the larger size classes, there were substantially more wood borer holes per square foot in the smaller size classes (Table 6) and in higher disks (Figures 1 and 2). Of the 1,327 disks collected over the first three years of this study, an average of 2.2 borer holes were found per disk (Table 6). There were slightly more holes (averaging 2.3 to 2.7) in disks that were approximately 30 to 80 feet off the ground and slightly fewer holes (averaging 1.6 to 2.0) for those disks taken from above and below this height range (data not shown). When the 1,327 disks were analyzed for five different size classes (4 to 7.9; 8 to 11.9; 12 to 15.9; 16 to 19.9; and 20+ inches), the means ranged from 2.0 to 2.4 wood borers per disk with no trends evident (data not shown). Since there were only slight differences in the number of wood borer holes based on disk height above the ground and there was no trend observed for number of holes in different size classes of disks, the greater number of wood borer holes per square foot in the smaller diameter class trees can probably best be explained by the fact that disk area increases exponentially as disk diameter increased incrementally. Therefore, since there are roughly the same number of insects attacking each disk, substantially more area will be affected on the smaller disks than the larger disks and thus the smaller trees than the larger trees.

Most insects identified (Table 1) are fairly common and are described as preferring injured, dying, or dead trees. *Tetropium velutium*, western larch borer, was the most abundant species from all samples. *Xylotrechus longitarsus* is recorded to infest Douglas-fir (*Pseudotsuga menziesii*) in the Northwest. *Dendroctonus pseudotsugae* is a primary bark beetle of Douglas-fir, but occasionally attacks western larch (Furniss and Carolin 1977). *Melanophila drummondi* is a very common buprestid that is prevalent in the West. *Trypodendron lineatum* was the only ambrosia beetle collected. This beetle is considered the "most damaging ambrosia beetle in the West" as populations can build up rapidly in susceptible trees or logging slash (Furniss and Carolin 1977); however, rarely in Montana (Gibson 2005). *Trypodendron lineatum* has contributed little to defect in this study to date.

Identifying insects most likely to infest a particular tree species at a particular location, and at what levels they can be expected, may help determine rate of defect development associated with wood borers. However, Kimmey (1955) noted that insects and fungi "are so intimately associated that their effects are best considered in combination rather than separately" in his study of the deterioration of five fire-killed conifer species in California. This appears to be true in Montana as well.

Stain

There was an increase in sapwood stain in all size classes from one to two years post-fire (Table 6). However, increase in stain seemed to slow down and there was a reduction in stain in the smallest size class from two to three years post-fire. Others have suggested that sapwood stain volume decreases in fire-killed conifers as some of the stained wood is consumed by

sapwood decay fungi (Kimmey 1955; Hadfield and Magelssen 2000). This is probably why we observed less stain. Smaller size classes generally contain a higher percentage of sapwood stain -- as expected due to larger percent of disk surface area containing sapwood in younger trees (Table 6). Sapwood stain affected a greater percent of disk surface area in the lower portion of the bole, except at the stump where stain levels remained low over both years (Figures 1 and 2).

Sapwood Decay

Sapwood decay has increasingly become a significant agent of change as years progressed (Table 6). As with sapwood stain, percent sapwood decay is greatest in smaller diameter trees due to higher percentage of sapwood. Post-fire sapwood decay was first detected in all size classes two years after the fire, and then increased substantially in all size classes three years post-fire. Sapwood decay generally followed the trend observed for sapwood stain, with the greatest decay occurring lower in the bole, but above ten feet (Figure 2). Diminishing sapwood stain and decay higher in the tree may be a result of increased drying that occurs in the smaller, more exposed, tops of the trees. The first *C. volvatus* conks were seen two years after the fire and the first *F. pinicola* conks were observed three years after the fire. Between three and four years post-fire, there was a very large increase in number of trees that developed conks.

Kimmey (1955) found three fungal species causing most deterioration of fire-killed conifers in California were species now known as *F. pinicola*, *C. volvatus*, and *T. abietinum* and that *F. pinicola* "caused the greatest proportion of decay in the deterioration process." *Fomitopsis pinicola* is believed to have caused the most sapwood decay in the Montana study thus far, evidenced by laboratory isolations three years after the fire and conk development four years post-fire. Those three fungal species are the most prolific fruiters after four years, but proportion of sapwood decay caused by *C. volvatus* and *T. abietinum* is not clear since neither were isolated from decay. Although no fruiting bodies have been observed, *S. sanguinolentum* was isolated from a single sample of sapwood decay both two and three years after the fire. *Stereum sanguinolentum* was also isolated from several samples of pre-existing heartwood decay during this study.

Checks

Although there does not appear to be a trend regarding deepest checks in different size classes, all size classes showed no checks one year after the fire; but had average deepest checks of greater than 60 millimeters (approximately 2 1/3 inches) two years post-fire (Table 6). Average deepest check length dropped, ranging from 34 millimeters in the 20+ inch size class to 54 millimeters in the 12-15.9 inch size class after the third year.

Two years after the fire, a trend developed showing average number of checks per disk increasing with size class. Trees ranged from less than 2 checks per disk in the smallest size class to almost 6 checks per disk in the largest size class. This variation may have been due to greater surface area associated with larger disks on the larger trees and the positive correlation of the number of checks (per foot of disk circumference) to disk height above the ground (Figure 1). The trend disappeared three years after the fire as all size class means dropped to less than one check per disk (Figure 2).

A reasonable explanation for reduction in both size and number of checks, three years after the fire, is that there was much less precipitation for three months prior to data collection the second year compared to three months prior to data collection the third year. In addition to more than four times the precipitation during that period in the third year compared to the second year, precipitation continued throughout much of the three weeks that data were collected in 2004. The difference in precipitation from year to year also helps to explain the loss of the positive trend in number of checks with height above the

ground two years post-fire (Figure 1) compared to three years post-fire (Figure 2).

Comparisons with Eastern Washington Study

After four years, Montana results have some similarities, but mostly differences, when compared to results of Hadfield and Magelssen's (1996, 1997, and 1998) eastern Washington study of fire-killed western larch. After four years, both studies found no natural tree falls. There was no bark loss in eastern Washington after four years, while 13% of dissected trees two and three years post-fire and 32 % of remaining trees four years post-fire had sloughing bark in Montana. In eastern Washington, all trees dissected from two to four years post-fire contained wood borers, while in Montana 98% contained wood borers two years post-fire and all trees contained wood borers three years post-fire.

All trees contained sapwood stain in both studies from year two through year four post-fire. All eastern Washington trees had checks two to four years post-fire, while 98% had peripheral checks two years post-fire and 70% had peripheral checks three years post-fire in Montana. While Hadfield and Magelssen reported no sapwood decay two years post-fire and only a trace three and four years post-fire, sapwood decay was found in 60% of the trees two years post-fire and all trees three years post-fire in Montana. And by three years, sapwood decay became the primary agent associated with defect in the Montana study. Hadfield and Magelssen found no conks after four years. In Montana, 3% (1 dissected tree) had conks after two years, 18% of the dissected trees had conks after three years, and 44% of all remaining trees contained conks after four years. Many of the differences seen between the two studies may be a result of different moisture regimes at different geographic locations as discussed in the previous report (Jackson 2004).

<u>Loss of Merchantable Volume</u>

Table 7 shows means for defects and gross volume for the ten trees in each size class for each year in both Scribner and Cubic Rules. Table 8 shows means for percentage of gross volume that defects affected for the ten trees in each size class for each year in both rules. These two tables are not directly interchangeable since larger trees contribute more to overall numbers than smaller trees in Table 7 and all trees contribute equally in Table 8. In most cases, post-fire defect values in Table 8 are higher than they would be if numbers were only a percentage of total post-fire defect volume in the ten trees divided by total gross volume of those ten trees. This suggests that a greater percentage of volume is affected by post-fire defect in smaller trees in each size class. This shows the trend seen across size classes (higher percentage of post-fire defect seen in smaller size classes compared to larger size classes) is also present within size classes. Although not as profound, in several cases we conversely see lower pre-existing defect numbers in Table 8 than would be expected if we were to determine percentages based on Table 7. This suggests pre-existing defects were more substantial in larger trees. Both higher post-fire defects and lower pre-fire defects are most evident at the bottom of the tables where the greatest number of trees (120) is used to develop means for "All Sizes" from "All Years."

Percent volume affected by post-fire defects has consistently been higher with decreasing diameter classes since year two; however, there wasn't a difference between size classes 12-15.9 inch and 16-19.9 inches three years after the fire. Two years after the fire, about 7% of cubic volume and 6% of board foot volume was lost to post-fire defects (calculations based on Table 3). Three years after the fire, 18% of cubic volume and 20% of board foot volume was lost to post-fire defects (calculations based on Table 5).

About 50% of cubic and board foot volume were lost to post-fire defects in the smallest size class (Table 8), while 11% cubic volume and 13% board foot volume was lost in the largest size class. Given that heartwood is generally accepted as more durable than sapwood in dead trees (Lowell, et. al. 1992), the greater heartwood/sapwood ratio seen with increasing size classes - and smaller direct and indirect impacts by wood borers and checks to larger trees - are probably the most important factors contributing to the different percent volume defects in the various size classes of fire-killed trees in this study. With all other factors equal, stands containing a greater proportion of smaller trees should be harvested sooner than those containing more large trees if timber yield is a management objective.

REFERENCES CITED

Cerezke, H.F. 1975. White-spotted sawyer beetles in logs. Northern Forest Research Centre, Edmonton, Alberta, Information Report, NOR-X129.

Furniss, R. L. and V. M. Carolin. 1977. Western Forest Insects. USDA Forest Service. Misc. Pub. 1339. 654p.

Gibson, K.E. 2005. *Personal communication*.

Hadfield, J. S., and Magelssen. R. M. 1997. Wood Changes in fire-killed Eastern Washington tree species--Year two progress report. USDA-Forest Service, Wenatchee National Forest, Wenatchee, WA. 34p.

Hadfield, J. S., and Magelssen. R. M. 1998. Wood Changes in fire-killed Eastern Washington tree species--Year three progress report. USDA-Forest Service, Wenatchee National Forest, Wenatchee, WA. 37p.

Hadfield, J. S., and Magelssen. R. M. 1999. Wood Changes in fire-killed Eastern Washington tree species--Year four progress report. USDA-Forest Service, Wenatchee National Forest, Wenatchee, WA. 35p.

Hadfield, J. S., and Magelssen. R. M. 2000. Wood Changes in fire-killed Eastern Washington tree species--Year five progress report. USDA-Forest Service, Wenatchee National Forest, Wenatchee, WA. 34p.

Jackson, M.B. 2004. Changes in Fire-killed Western Larch on the Glacier View Ranger District (Flathead National Forest), Montana: Establishment and Year One Report. USDA For. Serv. Forest Health Protection Rpt. 04-16. Missoula, MT. 13p.

Kimmey, J.W. 1955. Rate of Deterioration of Fire-killed Timber in California. USDA Circular No. 962. 22p.

Lowell, E.C., Willits, S.A., and Krahmer, R.L. 1992. Deterioration of Fire-Killed and Fire-Damaged Timber in the Western United States. USDA Forest Service Gen. Tech. Rep. PNW-GTR-292. 27p.

Post, K.E. and R.A. Werner. 1988. Wood borer distribution and damage in decked white spruce logs. Northern Journal of Applied Forestry. 5:49-51.

Vallentgoed, J. 1991. Some important wood borer related to export restrictions. Natural Resources, Canada, Canadian Forest Service, Forest Pest leaflet No. 74.

Werner, R.A. 2002. Effect of ecosystem disturbance on diversity of bark and wood-boring beetles (Coleoptera: Scolytidae, Buprestidae, Cerambycidae in white spruce (*Picea glauca* (Moench) Voss) ecosystems of Alaska. Research Paper PNW-RP-546. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 15 p.

Werner, R. 2003. *Personal communication.*

Werner, R.A. and K.E. Post. 1985. Effects of wood-boring insects and bark beetles on survival growth of burned white spruce. *In:* Juday, J.P. Dyrness, C.T. eds. Early results of the Rosie Creek fire research project 1984. Misc. Publ. 85-2. Fairbanks, AK. University of Alaska Fairbanks, Agriculture and Forestry Experiment Station: pgs.14-16.

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